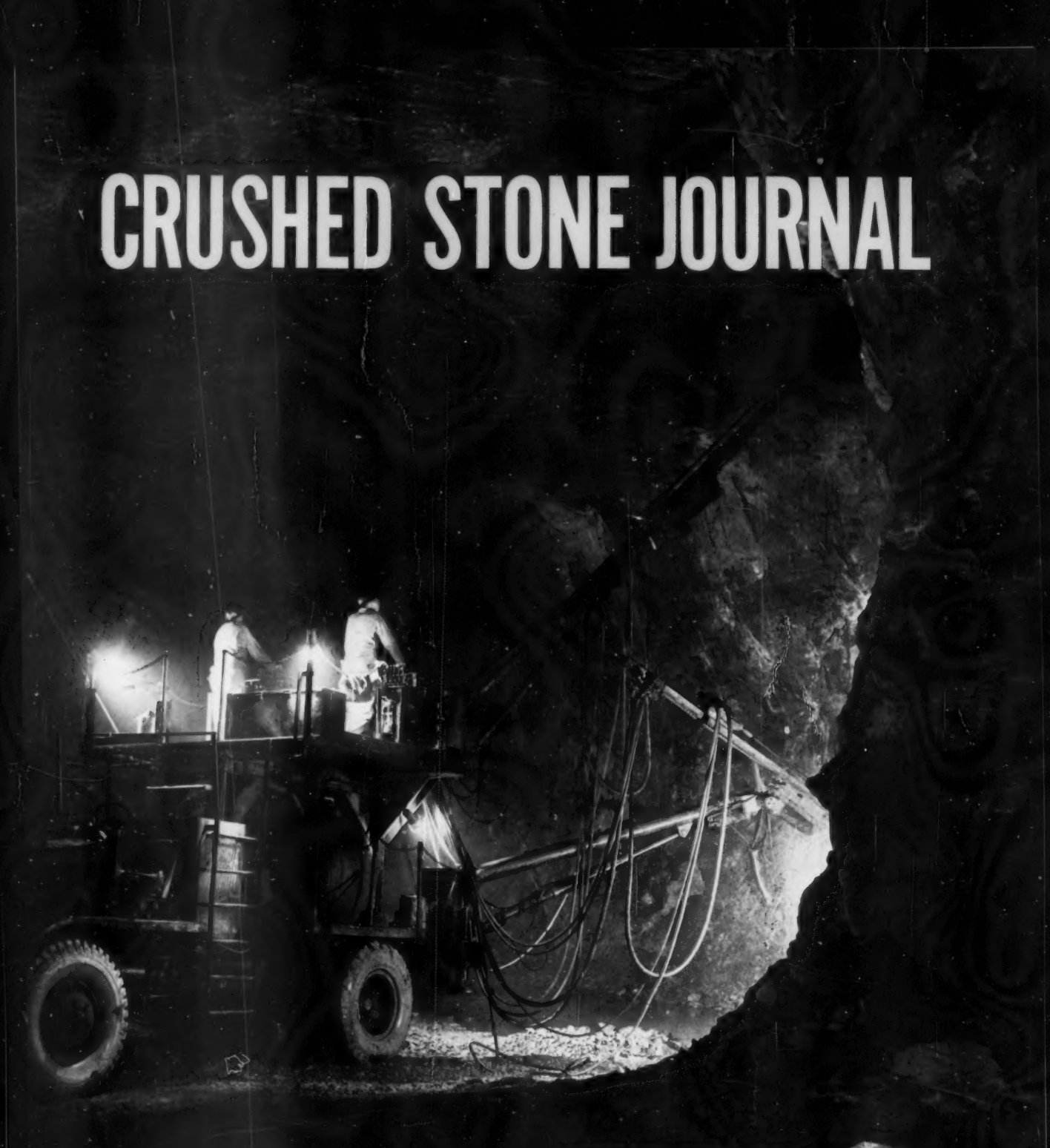
CRUSHED STONE JOURNAL



SEPTEMBER 1960

OFFICIAL PUBLICATION OF THE NATIONAL CRUSHED STONE ASSOCIATION

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44th ANNUAL CONVENTION

National Crushed Stone Association

January 17 - 20, 1961

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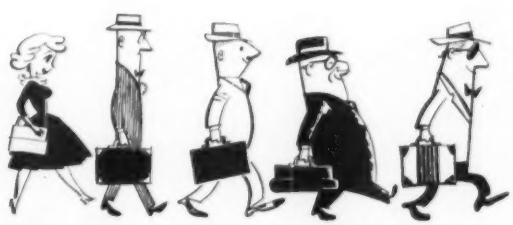

MAKE YOUR RESERVATIONS NOW

Crushed Stone Journal

Official Publication of the NATIONAL CRUSHED STONE ASSOCIATION

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NATIONAL CRUSHED STONE ASSOCIATION

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Cover Photograph — Kimballton Mine of Standard Lime and Cement Company Division of American-Marietta Company.

Congratulations to the Winners in the 1959 NCSA Safety Contest

The National Crushed Stone Association wishes to extend its heartiest congratulations to the winners of the NCSA Safety Contest.

The crushed stone industry can well take pride in the accomplishments of the 61 plants which operated 4,819,147 man-hours during 1959 without a disabling work injury.

Appropriate awards will be presented at the NCSA Annual Convention to be held January 17-20, 1961, at the Americana, Bal Harbour, Miami Beach, Florida.

The value of the Safety Contest is measured to a large degree by the number of participants. Plan now to enter your company's plants in the 1961 Contest. Full details may be obtained by contacting the Branch of Accident Analysis, Division of Safety, United States Bureau of Mines, Washington 25, D. C.

Awards Announced for 1959 National Crushed Stone Association Safety Contest[1]

By Elizabeth K. Elsner
Mary B. McNair

Under the Supervision of John C. Machisak, Chief
Branch of Accident Analysis
Division of Accident Prevention and Health
U. S. Bureau of Mines, Washington, D. C.

THE Bureau of Mines, United States Department of the Interior, reports that 59 of the 134 participants in the 1959 Safety Contest, sponsored by the National Crushed Stone Association, operated through the competitive year without a disabling work injury among their employees. In recognition of their outstanding safety records, each will receive the Association's Safety Award Plaque with a bar indicating the year of award and the man-hours operated during the year. This was the largest number of awards since the contest began in 1926. The 1959 event saw the greatest number of operations participating and the highest number of man-hours of exposure-to-hazard accumulated during the 34 year history of the contest.

The contest is divided into 5 groups, based on man-hours worked, as follows: GROUP I, 200,001 man-hours and over; GROUP II, 100,001 to 200,000 man-hours; GROUP III, 50,001 to 100,000 man-hours; GROUP IV, 30,001 to 50,000 man-hours; and GROUP V, 30,000 man-hours or less.

The National Crushed Stone Association presents a plaque with a bar of silver for the first year of disabling injury free operation. For the second, third, and fourth consecutive injury free years, additional silver bars are added. A non-consecutive disabling injury free year also earns a silver bar. Gold bars are the reward for 5 through 9 consecutive injury free years. For 10 or more years, a green safety bar is awarded. Each bar indicates the year of award and the man-hours of exposure.

The plant accumulating the greatest number of injury free man-hours in its respective group is considered the GROUP WINNER and the bar presented by the Association to his plant so indicates. In addition to the bar awarded to the 5 group winners, each employee and official of the winning operations receives a safety certificate from the Association. Each is inscribed with the employee's name, the plant name and location, and the name of the company.

The plant which extends its injury free record the greatest number of consecutive days and which has throughout the current competition period complied with all eligibility requirements of the contest, receives the annual Explosives Engineer Award, provided by the Explosives Engineer Magazine.

[1] The statistical tables accompanying this article will be printed as a Supplement and sent to readers of the Journal

Explosives Engineer Award

Since the release of this article it has been determined by the U. S. Bureau of Mines that the winner of the Explosives Engineer Award for 1959 is:

Kimballton Mine
Kimballton, Virginia
Standard Lime and Cement Company
Division of
American-Marietta Company

2,663 Days

September 16, 1952 December 31, 1959

This award is presented annually to the plant winning an NCSA Safety Award Plaque and which has the greatest number of consecutive days without a lost time disabling work injury.

The award made available through the courtesy of the Explosives Engineer Magazine will be presented at the 44th Annual Convention of the National Crushed Stone Association to be held January 17-20, 1961, at the Americana, Bal Harbour, Miami Beach, Florida.

The 1959 National Crushed Stone Association Safety Contest winners for operating without a disabling work injury during the competitive year are:

Group I

PLANTS WORKING 200,001 MAN-HOURS AND OVER

Port Inland Quarry, Gulliver, Michigan, Inland Lime and Stone Company, Division of Inland Steel Company, 451,317 man-hours

Lowellville Quarry, Lowellville, Ohio, Carbon Limestone Company, 366,988 man-hours

Clinton Point Quarry, New Hamburg, New York, New York Trap Rock Corporation, 340,112 man-hours

Krause Quarry No. 1, Columbia, Illinois, Columbia Quarry Company, 255,486 man-hours

Tomkins Cove Quarry, Tomkins Cove, New York, New York Trap Rock Corporation, 216,724 man-hours

Group II

PLANTS WORKING 100,001 TO 200,000 MAN-HOURS

Dan Quarry, Martinez, Georgia, Superior Stone Company, 177,333 man-hours

Kimballton Mine, Kimballton, Virginia, Standard Lime and Cement Company, Division of American-Marietta Company, 176,581 man-hours

Ives Quarry, Racine, Wisconsin, Consumers Company, Division of Vulcan Materials Company, 135,556 man-hours

Oriskany Falls No. 5 Quarry, Oriskany Falls, New York, Eastern Rock Products, Inc., 129,627 man-hours

New Bern Quarry, New Bern, North Carolina, Superior Stone Company, 117,395 man-hours

Pixley Mine, Independence, Missouri, Stewart Sand and Material Company, 114,771 man-hours

Pounding Mill Quarry, Pounding Mill, Virginia, Pounding Mill Quarry Corporation, 114,417 man-hours

Pleasant Gap Mine, Pleasant Gap, Pennsylvania, Standard Lime and Cement Company, Division of American-Marietta Company, 111,808 man-hours

Group III

PLANTS WORKING 50,001 TO 100,000 MAN-HOURS

McLeansville Quarry, McLeansville, North Carolina, Superior Stone Company, 99,900 man-hours

Blair Quarry, Blair, South Carolina, Palmetto Quarries Company, 90,737 man-hours

West Nyack Quarry, West Nyack, New York, New York Trap Rock Corporation, 87,334 man-hours

Lewisburg Mine, Lewisburg, Ohio, Marble Cliff Quarries Company, 75,516 man-hours

Chattanooga Quarry, Chattanooga, Tennessee, Vulcan Materials Company, Chattanooga Rock Products Division, 73,085 man-hours

Occoquan Quarry, Occoquan, Virginia, W. E. Graham and Sons Division, Vulcan Materials Company, 72,527 man-hours

Cape Girardeau Quarry, Cape Girardeau, Missouri, Federal Materials Company, 72,415 man-hours

Watertown Quarry, Watertown, New York, General Crushed Stone Company, 71,714 man-hours

Rockwood Quarry, Rockwood, Tennessee, Vulcan Materials Company, Lambert Brothers Division, 65,282 man-hours

Prospect Stone No. 6 Quarry, Prospect, New York, Eastern Rock Products, Inc., 64,304 man-hours

Montclair Heights Quarry, Montclair Heights, New Jersey, Houdaille Construction Materials, Inc., 64,069 man-hours

Bakers Quarry, Monroe, North Carolina, Superior Stone Company, 63,433 man-hours

Hermitage Quarry, Donaldson, Tennessee, Vulcan Materials Company, Lambert Brothers Division, 62,090 man-hours

Charlotte Quarry, Charlotte, North Carolina, Superior Stone Company, 62,034 man-hours

Pomona Quarry, Guilford, North Carolina, Superior Stone Company, 57,997 man-hours

Danville Quarry, Danville, Virginia, Vulcan Materials Company, Lambert Brothers Division, 57,410 man-hours

Auburn Quarry, Auburn, New York, General Crushed Stone Company, 53,115 man-hours

Rock Cut Quarry, Jamesville, New York, General Crushed Stone Company, 52,991 man-hours

Kingsport Quarry, Kingsport, Tennessee, Vulcan Materials Company, Lambert Brothers Division, 51,645 man-hours

Carey No. 3 Quarry, Carey, Ohio, National Lime and Stone Company, 51,025 man-hours

Group IV

PLANTS WORKING 30,001 TO 50,000 MAN-HOURS

Knoxville City Quarry, Knoxville, Tennessee, Vulcan Material Company, Lambert Brothers Division, 46,621 man-hours

Jordanville Quarry, Richfield Springs, New York, General Crushed Stone Company, 43,974 man-hours

Millington Quarry, Millington, New Jersey, Houdaille Construction Materials, Inc., 40,814 man-hours

Belgrade Quarry, Mayesville, North Carolina, Superior Stone Company, 37,731 man-hours

Wallingford No. 1 Quarry, Wallingford, Connecticut, New Haven Trap Rock Company, 37,517 man-hours

Semco Quarry, Osgood, Indiana, South Eastern Materials Corporation, 36,747 man-hours

Ashland Quarry, Ashland, Massachusetts, Bayer and Mingolla, Inc., 35,361 man-hours

Shawnee Quarry, Shawnee Hills, Ohio, Marble Cliff Quarries Company, 34,465 man-hours

Rock Hill Quarry, Quakertown, Pennsylvania, General Crushed Stone Company, 31,689 man-hours

Group V

PLANTS WORKING 30,000 OR FEWER MAN-HOURS

Franklin Mine, Franklin, Tennessee, Vulcan Materials Company, Lambert Brothers Division, 28,736 man-hours

Big Horn Quarry, Warren, Montana, Weaver Construction Company, 27,195 man-hours

Webster Quarry, Irvington, Kentucky, Kentucky Stone Company, 27,013 man-hours

Newport Quarry, Newport, Pennsylvania, Bradford Hills Quarry, Inc., 23,519 man-hours

White Haven Quarry, White Haven, Pennsylvania, General Crushed Stone Company, 23,374 man-hours

Buckland Quarry, Buckland, Ohio, National Lime and Stone Company, 22,275 man-hours

Rimer Quarry, Rimer, Ohio, National Lime and Stone Company, 21,775 man-hours

High Bridge Mine, Wilmore, Kentucky, Kentucky Stone Company, 21,619 man-hours

Cairo Quarry, Cairo, New York, Catskill Mountain Stone Corporation, 21,450 man-hours

Plainville No. 4 Quarry, Plainville, Connecticut, New Haven Trap Rock Company, 21,363 man-hours

Morgantown Quarry, Morgantown, Pennsylvania, Bradford Hills Quarry, Inc., 20,783 man-hours

Boonesboro Mine, Richmond, Kentucky, Kentucky Stone Company, 19,152 man-hours

Todd Quarry, Elkton, Kentucky, Kentucky Stone Company, 18,594 man-hours

Hudson Quarry, Hudson, New York, Catskill Mountain Stone Corporation, 17,850 man-hours

No. 4 Quarry, Knippa, Texas, Southwest Stone Company, 16,558 man-hours

Sevierville Quarry, Sevierville, Tennessee, Vulcan Materials Company, Lambert Brothers Division, 13,329 man-hours

Randville Quarry, Iron Mountain, Michigan, Superior Rock Products Company, 9,681 man-hours

Injury Free Operations

Employees of 61 operations, 54 quarries and 7 underground mines, worked 4,819,147 injury free man-hours. This total man-hours operation represented 41 per cent of the 11,882,336 man-hours worked by the 134 mines and quarries that participated in the 1959 Contest. "The perfect records of these plants clearly indicate that employees and management cooperated in effective daily safety programs," said Marling J. Ankeny, Director of the Bureau of Mines.

Injury Experience of Competing Plants

Injury experience at the 134 operations competing in the 1959 National Crushed Stone Association Safety Contest was better than in 1958 and much improved over the over-all average for the contest since its inception 34 years ago. The man-hours of exposure—11,882,336—were nearly 2 million more than in any other year. The injury severity rate of 3,436 days lost per million man-hours was 46 per cent lower than the 6,360 rate

for 1958 and 29 per cent lower than the 34 year average severity rate of 4,855. The injury frequency rate of 18 injuries per million man-hours was 14 per cent lower than the rate of 21 for 1958 and 31 per cent lower than the over-all average frequency rate of 26.

During 1959, competing companies experienced 220 disabling work injuries, of which 4 were fatal, 11 permanent total disabilities, and 205 temporary total disabilities. These 220 injuries resulted in 186 days lost time per injury, a marked improvement over the 296 days lost for each injury in 1958. The mark, however, represented a 4 day increase over the 34 year average of 182 days lost for each injury.

Of the operations enrolled in the 1959 National Crushed Stone Association Safety Contest, 117 were open quarries and 17 were underground mines. The injury rates for the 117 open quarries were decidedly lower than in 1958. The injury severity rate of 2,991 days lost per million man-hours worked in 1959 was 44 per cent lower than the rate of 5,385 for 1958 and 36 per cent less than the average rate of 4,671 for the 34 years of the contest. The injury frequency rate for 1959 (18 injuries per million man-hours worked) dropped 12 per cent below the corresponding rate of 20 for 1958. The 1959 frequency rate was 32 per cent less than the over-all rate of 26 for the 34 year period.

The 17 underground mines represented the greatest number ever entered in the contest. Injury experience at these mines was also more favorable in 1959 than in 1958. The severity rate of 7,906 was about 1/2 (49 per cent) the severity rate of 15,590 for 1958. However, it showed a 24 per cent increase over the 6,359 average severity rate for the 34 year history of the contest. The frequency rate for injuries at these underground mines was lower in 1959 than in 1958 or than the average rate for the 34 years of the contest. The frequency rate of 20 injuries per million man-hours of exposure in 1959 was 29 per cent better than the rate of 28 for 1958 and 22 per cent better than the average rate of 26 for the 34 year period.

Twenty-two states were represented by the 134 crushed stone operations participating in the 1959 contest. Twenty-one operations were in New York; 13 in Kentucky; 12 in Ohio; 11 each in Pennsylvania and Tennessee; 8 in North Carolina; 7 each in Illinois, Missouri, and Virginia; 6 in New Jersey; 4 each in Georgia, South Carolina, and Wisconsin; 3 each in Connecticut, Iowa, and Maryland; 2 each in Indiana, Massachusetts, Michigan, and Texas; and 1 each in Montana and Oklahoma.

Causes of Injuries

The frequency of injuries with stated causes was highest for falls of persons, which accounted for 19.6 per cent of the total. Haulage, handling materials, machinery, and falling objects accounted for 17, 12.4, 10.8, and 10.3 per cent, respectively, of all injuries with stated causes. These 5 classifications accounted for 136 injuries or 70 per cent of all injuries with stated causes. The severity of injuries by causes showed a different distribution from the frequency of injuries. Machinery accounted for 44.8 per cent of the days of disability for injuries with stated causes. Haulage was the next highest with 32.8 per cent of all days lost from injuries; flying objects caused 9.2 per cent; and falls of persons 8.0 per cent. Although injuries from machinery were responsible for only 10.8 per cent of the total injuries in 1959, they resulted in 44.8 per cent of the total days lost from injuries with stated causes due largely to the 2 fatal and 4 permanent partial injuries which accounted for 17,260 days charged.

The Contest

The annual contest for the promotion of safety in the crushed stone industry is sponsored by the National Crushed Stone Association and conducted by the Bureau of Mines, U. S. Department of the Interior. It is conducted under the same rules as the National Safety Competition, and the same records are used in both contests. To be eligible, a plant must have enrolled in the National Safety Competition and filed all statistical reports required of participants. There are two additional requirements for the crushed stone contest:

1. The plant must be operated by a company which is a member of the National Crushed Stone Association
2. The plant must have produced crushed stone for commercial use during the contest year

Applications for enrollment and rules governing the contest can be obtained from the Branch of Accident Analysis, Division of Accident Prevention and Health, Bureau of Mines, U. S. Department of the Interior, Washington 25, D. C./NCSA

Compaction of Asphaltic Concrete*

By John J. Laing

Chief, Road Equipment Branch
U. S. Bureau of Public Roads
Washington, D. C.

SOME of the most pressing problems in the field of highway production today involve the compaction of embankments, subgrades, base courses and surface courses. The more one delves into our current standards and procedural requirements for compaction of these various roadway elements, the more complicated the picture becomes.

There is considerable variance in thinking as to what should be the characteristics of the finished product with respect to density or to some measure to which future service behavior can be related. In many instances we are still requiring the same procedures and equipment that were employed years ago, although pavement designs and the character of the traffic using our highways have changed to a considerable extent. Some equipment requirements in construction specifications are either restrictive or obsolete, since provisions are not included for taking advantage of new developments which are capable of superior or more economical performance. If rigid procedural or equipment requirements are used, they tend to stifle the initiative of contractors in developing new methods and to retard the development of improved and more adaptable equipment on the part of manufacturers.

The topic under discussion today is the "Compaction of Asphaltic Concrete." Consideration of the compaction of asphaltic concrete surface courses and their supporting foundations is indeed timely, since about 16,000 miles of this type are now placed each year on the state highway systems alone.

The National Bituminous Concrete Association has recently adopted a 10-point improvement and quality control program in which the compaction problem has been given a very high priority.

* Presented at the Kentucky Highway Conference February 17, 1959. Reprinted from *American Highways*

Compaction of Base Courses

While most of these remarks will be directed towards compaction of surface courses, it will be necessary to discuss, to some extent, the compaction of other elements which are part of the total pavement design. As has been pointed out many times before, it is difficult to consider a pavement surface without giving recognition to the base and subbase courses. Needless to say, the base should have sufficient supporting ability to withstand, without deformation, the reaction of tire loads that are imposed on it from the wearing course.

This ability to support involves the characteristics of the materials as well as density and moisture conditions. There seems to be a growing realization that a desirable degree of compaction for all embankment and base materials cannot be expressed as a single percentage of the maximum density at optimum moisture. For example, 95 per cent may be too great for materials containing clay and insufficient for granular materials. A few states are using variable percentage requirements depending on the physical characteristics of the material used or its service record over a number of years. A majority of the states, however, are using a single percentage requirement for all materials used in base courses.

In addition to the prevailing ranges of density requirements, there is also a number of methods for the basic determination. We now have two methods under AASHO test procedures for determining maximum densities, and a number of states have adopted their own method. Since each method provides a different answer, there is little opportunity to benefit from the exchange of experience in procedures and equipment application between states.

In addition to the ranges in density requirement and the method of attaining the same, there is a wide spread in the requirements for the maximum thickness of the base course layers to be

compacted. It varies from a commonly used 3 to 5 in. to such maximum limits as 8 and 10 in.

Equipment Requirements

Most of the current construction specifications for base courses provide for or require the use of conventional steel wheel rollers, tamping rollers, and pneumatic tired rollers and, in some instances, the vibratory types.

Most of the pneumatic roller requirements do not provide for the use of the recently developed high pressure tires which appear to offer one solution for the densification of most types of base courses. The Michigan State Highway Department took a desirable step in their 1958 special provision covering test rolling with a heavy compactor by inserting the following requirement:

> "The contractor shall furnish to the engineer, charts or tabulations showing the contact areas and contact pressures for the full range of tire inflation pressures and for the full range of loadings for the tire furnished."

With this information the engineer can determine the effect of varying wheel loads and inflation pressures for the tire size and the prevailing soil conditions. Heretofore, the engineer has been unable to determine the net result of modifying ballast and tire pressures.

Contact areas along with contact pressures are of some importance when compacting or testing deep layers of soils, particularly in elastic materials where Boussinesq's theory[1] of pressure distribution is applicable. Tests conducted by the U. S. Corps of Engineers at Vicksburg, Miss., on large compactor size tires tested on lean clay soils show that the loss in pressure due to smaller contact area was not significant at depths of less than 10 in. When tire contact area was decreased about 18 per cent, a pressure loss of about 5 per cent under that exerted by the larger tire was experienced at depths of 5 in. below the surface. The pressure intensity of approximately 90 per cent of surface contact pressures was experienced at depths of 5 in. below the surface for the tire sizes and surface pressure employed. The smaller size tires may therefore have their place in base compaction. More will be devoted to the subject of tire pressure distribution later in this discussion.

Many current base construction specifications also exclude the use of the dynamic type compactors including the pad or plate types on which reports indicate very good results in compacting granular type bases including macadam courses. Engineers have misgivings with regard to some types of equipment attachments. Tests, however, have shown that the addition of a trailing vibratory compacting unit to a 3 wheel roller enabled the equipment to obtain a higher density than could be obtained with the static roller regardless of the number of passes made.

Vibratory steel wheel rollers are being used to a greater extent in compacting base courses. Most of the models used are of the towed type, although one small self-propelled roller of German manufacture was introduced in this country during the last two years and has demonstrated its ability to compact soil bases and asphaltic binder courses with a minimum number of passes.

There is a need for more performance information on many of the new rollers and compactors, particularly on the dynamic types, for various materials and conditions. A wide variance exists in the frequency of vibrations of the several vibratory models and in many of the manufacturers' claims on effective compaction depths and number of passes required for given density requirements. A considerable amount of basic research has been done on pad or plate type vibration by the California Institute of Technology with laboratory models in cooperation with the U. S. Navy Civil Engineering Corps. There have been no comprehensive tests made, however, with commercial models.

Good results have also been reported in the compaction of base courses with grid rollers and with segmented pad type rollers, but here again we need more information on performance for various materials and conditions.

The problems associated with the compaction of base courses certainly deserve more consideration than has been given them in the brief remarks contained in this paper. It will be necessary, however, to move on to the main topic of discussion—the compaction of asphaltic concrete surface courses. Some of the remarks made will also be applicable to base course compaction.

[1] A series of equations expressing stress components caused by perpendicular, point, surface force, at points within an elastic istoropic homogeneous mass which extends infinitely in all directions from a level surface

Compaction of Surface Courses

Surface Stability Requirements

First of all, it would be well to analyze what is being sought for in the stability of the final product. Based on available information, 26 of the 49 states and the Territory of Hawaii have density requirements for finished asphaltic concrete pavements. Twenty-seven states and Hawaii have specific requirements, and 1 state establishes the density after the job mix is established. Here in Kentucky, specifications require a "satisfactory density as determined by method of test designation by the engineer." Of the 28 states and territories having specific density requirements, 15 jurisdictions relate the requirement to a percentage of theortical density or a voidless mixture. The other 13 states base their percentage on the density of a laboratory mix. Not all these states identify the test for the laboratory design method used, but 3 indicated the Marshall method and another 2 the Hubbard-Field while several others indicated the California or Hveem method.

The range of requirements based on theoretical density varies from 85 per cent for binder courses to 99 per cent for surface courses. The range of requirements based on the density of laboratory mixes varies from 92 to 98 per cent. One state increases its percentage requirement of laboratory density from 93 to 95 per cent after September 1. Even when variances in mixes are considered, both ranges appear to be too great for products which are to be subjected to comparable truck tire loads.

With regard to the method of basing the density requirements, both the Asphalt Institute and our Bureau recommend a percentage based on a laboratory mix. This is because it is not always possible to attain a specified percentage of a voidless mixture without crushing the aggregate particles and thereby changing the character of the mix. A laboratory mix, on the other hand, always contains sufficient voids to allow for bleeding and for some degree of densification under traffic. A range of from 95 to 98 per cent of laboratory density would be a desirable goal in the compaction of asphaltic concrete surfaces.

Equipment Requirements

Practically all of the states have requirements for approved type rolling equipment for compacting asphaltic concrete surfaces. This includes those states which have also adopted an "end result" requirement in the form of a minimum density. The advantages of end result features are largely nullified, however, by specifying the equipment to be used and the method to be employed.

Steel Wheel Rollers

Steel wheel rollers which have changed little from a capacity standpoint for several decades remain the more commonly used units for compacting asphaltic concrete. A majority of the states require the use of tandem rollers for finish rolling and permit either tandem or 3 wheel on the breakdown rolling.

On the finish or final rolling, several states may require diagonal and/or cross rolling of the surface with tandem rollers. A number of asphalt technicians advocate this procedure to guard against undue post construction densification that often occurs under heavy traffic. Some of the objections to the steel wheel types, however, are their tendency to bridge over low spots and to confine the final degree of compaction achieved to a thin layer near the surface.

While there is reasonable uniformity in the general types of steel wheeled rollers required, there is a wide variation in the capacities as expressed in tons and minimum compression per inch of driving rolls. The tonnage requirements for tandems vary from 5 to 10 tons and on 3 wheel rollers from 8 to 12 tons. For 3 wheel rollers the minimum compression varies from 200 to 350 lb per in. of driving wheel. For tandem rollers the variance is from 160 to 400 lb per in. of driving wheel or a range of 150 per cent between the low and the high requirements.

There is no correlation between the density requirements and the above minimum roller capacities. For example, a state which specifies 90 per cent of theoretical density of the wearing course requires a greater compression (250 lb) on the driving wheel than a state (200 lb) which requires up to 98 per cent of theoretical density.

Torque converters are often desirable on tandem rollers which do the finish rolling due to the ease of reversing direction without scuffing the surface. Such rollers should be equipped with 2 speed transmission if compaction on steep grades (6 per cent and over) is contemplated.

Pneumatic Tired Rollers

One of the most significant developments in the field of asphaltic concrete compaction has been recent improvements in pneumatic rolling equip-

ment, particularly with the advent of torque converters and high pressure tires.

Many highway departments have discovered the potency of heavy truck tires in the densifying of asphaltic concrete pavements subsequent to construction. This post-construction densification occurs when the wearing surface softens under extreme summer heat with rutting often prevalent in the wheel tracks. Wheel rutting from truck traffic is not confined to isolated projects on our primary and secondary highways, but has been experienced on some of our well known and better engineered expressways, especially where flexible bases have been used.

TABLE I
CONTACT AREAS OF HIGHWAY TIRES AT LOADS AND INFLATIONS SHOWN

Truck Tire Size	Ply	Inflation Pressure (psi)	Wheel Load (lb)	Contact Area (sq in.)	Computed Average Contact Pressure (psi)
7.50x20	8	65	2,740	48.4	56.6
8.25x20	10	70	3,330	50.5	65.9
9.00x20	10	70	3,960	60.6	65.3
10.00x20	12	75	4,580	71.8	63.8
11.00x20	12	80	4,850	67.4	72.0
11.00x22	12	70	4,750	75.3	63.1

Past experience seems to infer that where rutting of the asphaltic concrete surface has occurred in the wheel tracks, the base or surface courses or both were compacted during construction with equipment that was not capable of exerting the pressures produced by the heavier truck tires used today.

Early last year the Goodyear Tire and Rubber Company furnished our Bureau with information on contact area on truck tires for manufacturer's recommended inflation pressures and rated wheel loads. (See Table I) From this information it was possible to compute the average contact pressure for the various sizes. The term *average contact pressure* is used because the pressure is not constant throughout the elliptical contact pattern of the tire. The average contact pressure is obtained by dividing the contact into the wheel load to obtain pounds per square inch or "psi." Contact areas are obtained for different wheel loads and inflation pressures by tracing the contact patterns on a glass or steel plate with the tire in a static position. The following is a tabulation showing this data for the more popular sizes used on the heavier truck combinations.

There are several other tires, notably in the 7.50x15-12 ply and 14.00x20-18 ply sizes, which produce contact pressures up to 93.4 psi and 82.5 psi, respectively. However, these tire sizes are used to only a limited extent.

A study[2] made by the Division of Highway Transport of our Bureau of the air inflation pressures in operating truck tires revealed that the current practice was to operate at average hot inflation pressures of about 10 per cent above the tire manufacturers' recommendation. While this would increase the average contact pressures shown in Table I, the study also revealed that maximum wheel loads were seldom used in actual operations. Accordingly, it is believed that the contact pressure shown on Table I may be considered the maximums to be expected in normal use. In the compacting or densifying of asphaltic concrete at the intermediate or semifinal stage with pneumatic tired rollers, it is believed that the rollers used should be capable of exerting an average contact pressure *of at least 80 psi.* The maximum required will depend to some extent on the characteristics of the mix.

All of the three currently manufactured smooth compactor tire sizes of the ply ratings indicated in Table II are capable of exerting average contact pressures of 80 psi and over.

The tabulation below does not show the maximum contact pressure which can be exerted by each tire size, but serves to illustrate that all sizes are capable of exerting at least 80 psi. The two smaller sizes are also manufactured in 12 ply sizes which along with the 13.00x24-18 ply size can be inflated to a maximum of 100 psi with standard rims and thereby obtain contact pressures approaching and exceeding 100 psi.

TABLE II

Tire Size	Ply	Inflation Pressure (psi)	Wheel Load (lb)	Average Contact Pressure (psi)
7.50x15	10	90	5,130	82.6
9.00x20	10	90	8,000	83.0
13.00x24	18	90	12,000	88.2 (Approx.)

Compactor tires are rated for given wheel loads and inflation pressures (such as for the 7.50x15 and 9.00x20 sizes listed above), and the tire pres-

[2] Public Roads, Vol. 28, No. 22, Feb. 1958

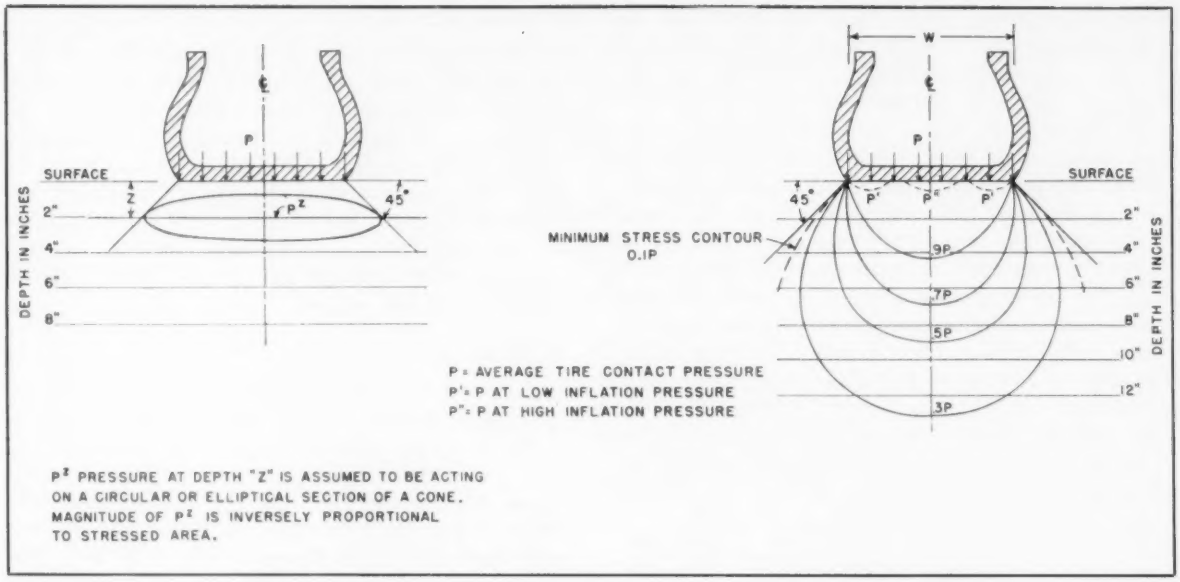

FIGURE 1
CONE OF PRESSURE
(As Assumed From Boussinesq's Formulas)

FIGURE 2
TYPICAL PRESSURE BULBS
Showing Stress Distribution as Influenced by Tire Contact Pressures

sures and wheel loads may be reduced or increased within allowable limits of deflection. As inflation pressure is increased or decreased, tire manufacturers recommend that ballast be adjusted accordingly.

During the past year there have been some discussions relative to the pressure distribution of wheel loads below the surface. At least one group holds that the Boussinesq theory is applicable to all materials and conditions and the surface contact pressure is assumed to be distributed below the surface in the shape of a cone radiating at an angle of 45 degrees from the perimeter of the tire contact pattern. (See Figure 1)

Under this assumption, for which we do not find substantiating evidence, some of the smaller compactor tires would lose 30 per cent of their compacting effort 1 in. below the surface, about 50 per cent about 2 in. below the surface, etc. I am sure that flexible pavement designers would appreciate the dissipation of heavy truck tire loads at such rates. Actually, Boussinesq's theory is applicable only for certain elastic materials of a homogeneous character which have constant properties of displacement in all directions. Very few highway materials are in this category.

The subsurface influence of a given contact pressure on a circular or elliptical tire pattern appears more likely to take on the form of pressure bulbs in which the points of equal stress below the surface are shown as contours. Figure 2 exemplifies typical pressure bulb distributions of stress influence lines for a single homogeneous layer of materials.

In examining the contours of equal pressures in Figure 2, it is to be noted that the apex or center of the bulbs is located on an axis through the center of the tire both for normal tire pressures and for high inflations where the contact pressure at the center of the tire (P") would greatly exceed that under the sidewalls. Conversely, under a low inflation the maximum pressure (P') would be at the edges where the tire receives structural support from the sidewalls. Under these conditions the material being processed receives additional horizontal pressures as well as the vertical pressures.

Work done in both the highway and agricultural fields as well as in the transportation industry with pressure distribution on elastic materials for circular and strip loads indicates that pressure equal to 0.9 of the surface contact pressure (0.9 P)

can be expected to depths of at least 3 in. below the surface. This pressure influence of 0.9 P would act on approximately 2/3 of the tire width. To get complete coverage of an area to 0.9 P at a depth of 3 in. in a single pass, it would be necessary to have at least some overlap of the front tire tracks with the tires on the rear axle.

Concentrated loads which are applied by truck tires when the highway is in service will not exceed the maximum pressures now obtainable with the smaller compactor tires on or below the roadway surface. In view of the foregoing, it is believed that compactor tire size is not significant in the compaction of asphaltic concrete courses to the depths of 2 1/2 and 3 in. if the roller tires are properly spaced for overlap.

In addition to the high pressure pneumatic rolling of asphaltic concrete, there is some thinking among asphalt technicians that a pneumatic roller with low pressure inflation should be used for the breakdown rolling. When compactor tires are inflated at a low range, 30 to 40 psi, the tire contact pattern is concave and the horizontal forces exerted assist in particle placement and the kneading itself.

The question may now be asked, "Why aren't we making greater use of pneumatic tired rollers in compacting asphaltic concrete?" Such a question could be answered as follows:

1. Most pneumatic roller specifications are either meaningless or are restrictive because they have been written around a single model.
2. There has been a lack of basic technical information on which a non-restrictive specification could be based. (This includes such information as ground or contact pressures for allowable compactor tire inflation ranges and wheel loads.)[3]

Only in the last several years has it been recognized that the average ground pressure exerted by pneumatic tires is not limited to or necessarily equal to inflation pressure.

Let's examine some of the current methods used to rate the capacity of pneumatic rollers in construction specifications by the 12 states in which their use on asphaltic concrete is mandatory and an additional 12 states which permit or may require their use:

[3] A considerable amount of such information has been developed recently by tire manufacturers

1. *Gross Weight*

Several states rate the pneumatic rollers approved for asphaltic concrete compaction by gross weight, and in one instance the number of tires is specified. Neither of these ratings is conclusive without information on the tire size and ply rating. The same applies to the so-called 50 ton compactor which for all practical purposes is a 30 ton compactor when ballasted for this weight. Several manufacturers advertise on the basis of maximum gross weight.

2. *Wheel or Tire Loads*

A number of states specify minimum wheel or tire loads varying from 1,000 to 8,000 lb. This criteria is also meaningless without tire size and ply rating data. Several of the minimum wheel loads as now specified are well below the minimum of the smallest compactor tire manufactured and must be termed obsolete. Wheel loads in the lower ranges (2,000 to 2,500 lb) would be suitable for breakdown rolling purposes, but would be of little or no value for densification purposes in intermediate or semifinal rolling.

3. *Weight Per Inch of Tire Width*

Quite a number of states rate the required pneumatic rollers by the "weight per inch of tire width." This rating has little or no significance because the tires make an elliptical pattern and the weight per linear inch varies both for tire sizes and within the pattern itself. This rating seems to be a carry-over from the rating of steel wheel rollers which actually produce rectangular contact patterns under most conditions. If the "weight per inch of tire width" requirements were converted into wheel loads on the basis of tire contact width for various tire sizes, it would represent a sizeable range in the contact pressure exerted. For example, a requirement of 600 lb "per inch of tire width" could convert into a contact pressure of 62.0 psi for one size tire and into a contact pressure of 81.6 psi for another size tire. This is a differential of over 30 per cent in compacting effort.

4. *Inflation Pressure*

If tire inflation pressure is specified, it could represent a considerable range in contact pressure due to tire sizes and wheel loads.

It can be seen from the foregoing that of all the current roller requirements those used for pneu-

TABLE III

CONTACT AREAS AND GROUND PRESSURES

9.00x20—12 Ply Smooth Compactor Tire on 7.00L Rim at Various Loads and Inflations

Load	55 psi Contact Area	55 psi Press.	65 psi Contact Area	65 psi Press.	75 psi Contact Area	75 psi Press.	80 psi Contact Area	80 psi Press.	95 psi Contact Area	95 psi Press.	105 psi Contact Area	105 psi Press.
4,500	70.0	64.4	—	—	—	—	—	—	—	—	—	—
4,750	72.0	66.0	—	—	—	—	—	—	—	—	—	—
5,000	73.9	67.8	68.5	73.0	—	—	—	—	—	—	—	—
5,250	77.4	68.0	71.0	74.0	—	—	—	—	—	—	—	—
5,500	79.5	69.3	73.0	75.4	—	—	—	—	—	—	—	—
5,750	81.5	70.6	74.5	77.3	70.5	81.6	—	—	—	—	—	—
6,000	84.5	71.0	77.3	77.6	72.2	83.1	70.0	85.7	—	—	—	—
6,250	87.0	72.0	79.6	78.2	73.7	84.8	71.3	87.2	—	—	—	—
6,500	89.5	72.6	81.6	79.6	75.7	85.8	73.0	89.0	—	—	—	—
6,750	91.5	73.8	83.7	80.6	77.6	87.0	74.6	90.3	—	—	—	—
7,000	94.8	74.0	85.8	81.6	79.6	87.8	76.5	91.5	69.5	100.0	—	—
7,250	97.0	74.8	88.0	82.5	81.5	89.0	78.0	93.0	71.1	102.0	—	—
7,500	99.0	75.6	90.0	83.3	83.1	90.1	80.1	93.5	73.0	102.8	—	—
7,750	—	—	92.1	84.0	86.0	90.2	81.6	95.0	74.3	104.2	70.5	110.0
8,000	—	—	94.5	84.6	89.0	89.8	83.4	96.2	76.0	105.2	71.6	111.5
8,250	—	—	96.5	85.5	91.2	90.5	85.4	96.8	77.5	106.5	73.1	112.8
8,500	—	—	98.6	86.1	93.0	91.4	87.4	97.4	78.7	108.0	74.4	114.3
8,750	—	—	101.4	86.2	95.0	92.2	88.4	99.3	80.5	108.6	75.7	115.5
9,000	—	—	—	—	96.5	93.3	90.6	99.4	81.8	111.0	77.3	116.5
9,250	—	—	—	—	98.5	94.0	92.5	100.0	83.4	111.1	78.5	117.9
9,500	—	—	—	—	100.6	94.5	94.0	101.1	85.0	112.7	80.0	119.0
9,750	—	—	—	—	—	—	95.5	102.0	86.5	112.8	81.5	119.5
10,000	—	—	—	—	—	—	97.1	103.0	88.0	113.7	82.6	121.0
10,250	—	—	—	—	—	—	99.0	103.5	89.7	114.1	84.1	121.9
10,500	—	—	—	—	—	—	101.1	105.0	91.0	115.5	85.6	122.6
10,750	—	—	—	—	—	—	—	—	92.5	116.1	87.0	123.4
11,000	—	—	—	—	—	—	—	—	94.0	117.0	88.3	124.7
11,250	—	—	—	—	—	—	—	—	95.6	117.6	90.0	125.0
11,500	—	—	—	—	—	—	—	—	97.0	118.6	91.3	126.1
11,750	—	—	—	—	—	—	—	—	98.5	119.7	92.5	127.2
12,000	—	—	—	—	—	—	—	—	100.0	120.0	94.1	127.6
12,250	—	—	—	—	—	—	—	—	—	—	95.5	128.5
12,500	—	—	—	—	—	—	—	—	—	—	97.0	128.9
12,750	—	—	—	—	—	—	—	—	—	—	98.5	129.6
13,000	—	—	—	—	—	—	—	—	—	—	99.4	130.0

Courtesy of Goodyear Tire and Rubber Company

Underscoring denotes load and inflation for normal deflection of tire
Minimum deflection for above figures is *1.41 in.*
Maximum deflection for above figures is *2.35 in.*

matic rollers are the least expressive of the equipment's ability to perform.

The ability of smooth compactor tires to exert a given contact or ground pressure is dependent on the following factors:

a. Tire size
b. Ply rating
c. Wheel load
d. Tire inflation pressure

It would be possible to specify all of the above factors and still have a restrictive specification because rollers equipped with other size tires under different wheel loads would be capable of exerting comparable contact pressures.

It is our belief that the contact pressure range should be the principal criteria in rating the pneumatic rollers to be used in compacting asphaltic concrete courses and thin layers of base materials.

Until now we have pointed out some of the apparent deficiencies in rating pneumatic rollers. On the positive side it might be worth while to suggest some preliminary guides for describing desirable over-all characteristics of pneumatic tired rollers to be used in compacting asphalt concrete

courses and thin layers of base materials pending the development of suitable performance criteria. First of all, a minimum width of about 6 1/2 ft would be desirable from a production standpoint. The unit should be equipped with smooth wide tread compactor tires capable of exerting an average contact pressure variable from 60 to 95 psi uniformly over the surface by adjusting ballast and tire inflation pressure. The wheels should be so mounted as to prevent scuffing of the surface during rolling or turning with provisions for wetting and cleaning tires.

The mentioning of desirable pneumatic roller characteristics in this paper is not necessarily a recommendation for their inclusion in a construction specification. While a number of current models could measure up to these suggested guides, a new model might be introduced this year or next year which would make these features obsolete or restrictive. As you know, the revision and reprinting of construction specifications is a time consuming procedure. It would seem preferable to develop an "end result" specification where density or other finished characteristics, in addition to profile and crown tolerances, would be specified.

Vibratory Compaction Equipment

The principal of vibratory compaction has been incorporated in the asphaltic concrete lay-down process for some time. An American manufacturer has recently introduced a 3 wheel tandem roller with vibration on the middle roll. This roller may have application in the compaction of both binder and surface courses of asphaltic concrete. The vibratory roll is retractable which will allow the roller to be used as a static unit for finish rolling.

As previously mentioned, a small self-propelled vibratory roller with vibration on the driving wheel of the tandem was introduced in this country about two years ago. It has demonstrated its ability to compact granular bases and asphaltic binder courses to required densities with a minimum number of passes. More performance information is needed on both of these vibratory rollers.

Although the use of vibratory compacting equipment on asphalt concrete courses has been limited, there is a feeling in some quarters that application of the dynamic principles offers one of the solutions to the compaction of asphaltic concrete.

It has been a pleasure to appear here today to give you some of our ideas on the compaction of asphaltic concrete pavements. While some progress has been made recently in obtaining a better understanding of the problem, much remains to be accomplished, particularly in obtaining unbiased appraisals of equipment performance and in narrowing down the wide spread in other procedural or end result requirements./NCSA

Highway Funds Apportioned For Fiscal Year 1962

Secretary of Commerce Frederick H. Mueller apportioned $2,893,750,000 of federal aid to the states for the fiscal year 1962, which began July 1, 1961, to continue the expanded national highway program launched in 1956.

The apportionments include $2,200,000,000 for the National System of Interstate and Defense Highways, the full amount authorized for fiscal year 1962 by the Federal Aid Highway Act of 1958; and $693,750,000 for the federal aid primary and secondary systems and their urban extensions, the so-called ABC program, authorized by the Federal Aid Highway Act of 1960.

The announcement of the amounts of funds available for the fiscal year 1962 provides almost a full year's lead time to the states for adequate planning of their use of the money, and thus assures orderly progress in the program.

The new apportionment of $2.2 billion for the interstate system is the full amount authorized for the interstate system for fiscal year 1962 by the 1958 Act.

The new apportionment for the regular or so-called ABC federal aid program for the fiscal year 1962 totals $693,750,000.

The continuing program of federal assistance for the improvement of the federal aid primary and secondary systems and their urban extensions has also made an outstanding record of progress, with almost $9 billion worth of work and almost 120,000 miles of construction contracts completed or under way. /NCSA

Let's Stop Talking About Highway Hypnosis[1]

By Edwin L. Baron

Director
Hypnotism Institute
Chicago, Illinois

NOT too long ago, I spoke before a group of teamsters and their families on the subject of "highway hypnosis."

In order to point up the part that suggestion is playing in inducing sleep on the highways, I asked the entire audience to participate in an experiment. Each was asked to sit up in his chair and imagine that he was sitting behind the wheel of his truck or private car.

I then began slowly: "You're sitting at a wheel driving along the highway at a constant rate of speed. You hear the purring of the engine and the hum of your tires. Along the left side there is a white line going past you, and along your right side is the edge of the road also going by. Occasionally a car comes along from the opposite direction and whizzes by. The sounds are monotonous. The lines continue going on and on and on . . . "

I continued this for several minutes, and then . . .

"As you're listening to the hum of the tires and watching the road ahead, you begin to get tired. You begin to get sleepy. You're getting very tired, very sleepy. Your eyes want to close. It is very hard to keep them open. If you find you can't keep them open any longer, you may let them close. . . . "

As I talked, I could see eyes closing and heads dropping down to chests. When I had been talking about 10 minutes, nearly half the audience was asleep.

As a speaker, I should have been outraged to think that I had put half my audience to sleep. But as a teacher of hypnotism, I was delighted—and also alarmed—for I had dramatized the kind of thing that some safety people are doing on an astronomical scale!

In other words, these safety people, by pre-conditioning the minds of the public, are actually condemning drivers to injury and death!

A little knowledge is a dangerous thing. Safety people usually do a good job in their own field, but I question their advice on hypnosis and their understanding of hypnosis. By setting themselves up as authorities on hypnosis they are causing more accidents and possible deaths than they realize—primarily because this condition they call "highway hypnosis" is not hypnosis. It is pure mental and physical fatigue. Because they are referring to it as "highway hypnosis" they are planting the suggestion in people's minds that they will become hypnotized when driving for a long period of time. Many people who are highly susceptible unconsciously accept the suggestion and so become hypnotized.

Suggestion Works

To illustrate, one of my students, a highly susceptible hypnotic subject, reported that whenever she drove on the highway she became tremendously sleepy and had to pull off the road. This happened after short trips almost without exception. In talking to her, I learned that she had done a lot of reading about highway safety and hypnotics and was indoctrinated with the idea that highway driving induces hypnosis. I finally convinced her that she was being hypnotized by these stories—that when she accepted the belief that she *would* be hypnotized, *she was actually becoming hypnotized while driving.*

Understanding what was now taking place and suggesting to herself that she would never again be hypnotized while driving, she succeeded in avoiding sleepiness, even on long trips.

There are several fundamental concepts in hypnosis of which the safety people who promote the term "highway hypnosis" are apparently unaware. First, *hypnosis must be accompanied by suggestion*, and secondly, *once a person is hypnotized, he becomes hypnotized more easily each succeeding time*, especially when the same technique is ap-

[1] Reprinted from *Traffic Safety*, December 1959

plied. So let us analyze "highway hypnosis" in terms of these two concepts.

To begin with, it is being constantly suggested to the driver that he will be hypnotized by continued monotonous driving—listening to the hum of the engine and the noise of the tire, watching a white line on the left, and the edge of the road on the right, eyes fixed on the road ahead, hands in a fairly fixed place, body always in a position that offers very little movement.

Through constant repetition, this idea takes hold subconsciously. A driver who has been subjected to such propaganda will experience the reactions he has been conditioned to expect. After he has been on the road a while he will begin to get sleepy or he may begin to have hallucinations.

I believe the driver who has never read any advice on highway driving nor heard the expression "highway hypnosis," will be able to drive for a longer period of time before beginning to feel fatigued. He will not subconsciously think himself into fatigue.

The second factor is the conditioning and the subsequent easier inductions of hypnosis each succeeding time it is tried. When a person has been driving for a period of time and begins to feel sleepy, he may fight it or he may pull over to the side of the road to nap. As a rule if he naps he will feel alert and very much refreshed soon after awakening. He can then resume driving and continue for quite a long period of time without any further fatigue.

Susceptibility Increases

If, however, he is truly hypnotized, subjecting himself to the same conditions that originally brought on his fatigue will cause him to become sleepy again in a much shorter period of time than before. Perhaps within a few minutes he will again be fatigued and sleepy and may have to pull off the road to take another nap. This will continue over and over again—and each time his period of alertness will be of shorter duration.

There are also reports of drivers having hallucinations—seeing imaginary obstacles such as buildings, trees, animals, curves in the road. This, too, has been attributed to the condition called "highway hypnosis." Here, too, I must disagree.

I feel certain that the reader has upon occasion dozed off for a few moments sitting in his chair or lying down and that he has dreamed that he is awakening and seeing certain things or people. This is probably what is taking place when there is physical and mental fatigue. The driver with his eyes open has actually dozed and dreamed, the dream taking the form of the obstacles he imagines he sees. In order for this to be hypnosis, the dream and the things he sees would have to be suggested to him. *As the suggestion is not present, this could not be hypnosis.*

Every authority on hypnosis recognizes the relationship of association to hypnosis. Some even define hypnosis as "suggestion." I do not accept the fact that hypnosis is suggestion, but I am aware of the close association of these two and the necessity of *suggestion to induce hypnosis* which subsequently causes an even greater ability to accept further suggestion.

Too Many Hypnotists?

Safety people, in permitting the expression and the concept of highway hypnosis to grow unrestrained *have pre-conditioned many drivers to accept the idea that they are going to be hypnotized while driving, and the subconscious mind, holding this suggestion, actually carries it out.* It will never be known how many people have been hypnotized by safety people nor how many people have been involved in accidents, nor how many people have been injured or killed.

What can the safety people do about this?

First, stop using the expression "highway hypnosis." It's catchy, I'll admit, but this is the type of catchiness that breeds disaster. Call it "highway fatigue" or "highway sleepiness," which is exactly what it is. The same effects can be pointed out and attributed to this highway fatigue or sleepiness as are now being attributed to hypnosis.

However, if drivers recognize this as pure fatigue it will be easier for them to accept the fact without the ensuing dangers.

Second, continue to urge people to pull off the highway for a brief rest when they feel sleepy or tired.

Third, continue to offer helpful suggestions on combating fatigue. Here are some.

Try to shift the line of vision to things on either side, as well as on the road.

Stop at occasional intervals—either every hour or about every 100 miles maximum—for a rest, to stretch the legs and to get refreshments. Tiredness can often be induced by having too little in the stomach as well as having too much./NCSA

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Halsted St. and 48th Place, Chicago 9, Ill.

Jaw and Roll Crushers; Vibrator, Revolving, and Scrubber Screens; Drag Washers; Bucket Elevators; Belt Conveyors; Bins; Apron and Plate Feeders; Portable Gravel and Rock Crushing, Screening, and Washing Plants; Stationary Crushing, Screening, and Washing Plants; Hammermills

Differential Co.

P. O. Box 238, Findlay, Ohio

Side Dump "Wagon Trains", Mine Cars, Locomotives, Car Dumpers

Dixon Supply Co.

3104 Fourth Ave., South, Birmingham 5, Ala.

Conveyors—Belt

Drill Carrier Corp.

P. O. Box 628, Salem, Va.

"Air-Trac" Drill Carrier

Du Pont of Canada Ltd.

85 Eglinton Ave., East, Toronto 12, Ontario, Canada

Explosives and Blasting Supplies

Du Pont, E. I., de Nemours & Co.

Wilmington 98, Del.

Explosives and Blasting Supplies

Dustex Corp.

25 Anderson Road, Buffalo 25, N. Y.

Dust Collecting Equipment; Dust Control Systems; Feeders

Eagle Crusher Co., Inc.

900 Harding Way East, Galion, Ohio

Crushers; Pulverizers; Hammermills; 4-Cage Disintegrating Mills; Portable Crushing Plants

Eagle Iron Works

P. O. Box 934, Des Moines 4, Iowa

Fine Material Screw Washers—Classifiers—Dehydrators; Coarse Material Screw and Log Washers—Dewaterers; Water Scalping and Fine Material Classifying Tanks; Stabilized Base Material Mixers; Drop Balls—Ni-Hard and Semi-Steel; "Swintek" Screen Chain Cutter Dredging Ladders; Revolving Cutter Head Dredging Ladders

Easton Car & Construction Co.

Easton, Pa.

Off-Highway Transportation: Quarry Hauling Systems—Heavy-Duty Dump Trailers, Truck Bodies, and Cars for Mines, Quarries, and Earth Moving

Electric Steel Foundry Co.

2141 N. W. 25th Ave., Portland 10, Oreg.

Esco Dragline Buckets, Shovel Dippers, Bucket Teeth, Crusher Wearing Parts, Cutting Edges and End Bits

Ensign-Bickford Co.

660 Hopmeadow St., P. O. Box 308, Simsbury, Conn.

Primacord-Bickford Detonating Fuse and Safety Fuse

Euclid Division
General Motors Corp.

1361 Chardon Road, Cleveland 17, Ohio

Heavy-Duty Trucks and Dump Trailers for "Off-Highway" Hauls, Loaders for Earth Excavation, Single and Twin Engine Earth Moving Scrapers, Crawler Tractors

Frog, Switch & Mfg. Co.
Manganese Steel Dept.

Carlisle, Pa.

"Indian Brand" Manganese Steel Castings for All Types of Jaw, Gyratory, and Pulverizing Crushers; Dippers, Teeth, Treads, and Other Parts for Power Excavating Equipment; Other Miscellaneous Manganese Steel Castings; Railroad and Mine Frogs, Switches, Crossings

Manufacturers Division – National Crushed Stone Association
(continued)

Gardner-Denver Co.

South Front St., Quincy, Ill.

Portable and Stationary Compressors, Rock Drills, "Air-Tracs," Self-Propelled Drills, Portable Rotary Drills, Sectional Drill Rods and Accessories, Air Hoists, Slusher Hoists, "Mole-Drills," Paving Breakers, Drill Steel, Gads, etc.

General Electric Co.
Locomotive & Car Equipment Dept.

2901 East Lake Road, Erie 1, Pa.

Electrical Apparatus, Locomotives

Geophysical Specialties Co.

15409 Robinwood Drive, Hopkins, Minn.

Miniature Engineering Seismograph—Model, MD-1—for Use in Locating and Mapping Sub-Surface Rock Topography

Gill Rock Drill Co., Inc.

P. O. Box 251, Lebanon, Pa.

Well Drill Tools and Supplies

Gilson Screen Co.

110 Center St., Malinta, Ohio

Gilson Testing Screen, Gilson "Porta-Screen," Accessories for Test Sizing of Concrete Aggregates

Goodrich, B. F., Industrial Products Co.

500 South Main St., Akron 18, Ohio

Industrial Rubber Products—Belting (Conveyor, Elevator, Transmission), V-Belts, Hose (Air, Water, Steam, Suction, Misc.); Rubber Chute Lining; Storage Batteries (Automobile, Truck, Tractor); Tires (Automobile, Truck, Off-the-Road); Tubes (Automobile, Truck, Off-the-Road); Industrial Tires and Tubes

Goodyear Tire & Rubber Co.

Akron 16, Ohio

Airfoam; Industrial Rubber Products—Belting (Conveyor, Elevator, Transmission); Hose (Air, Water, Steam, Suction, Miscellaneous); Chute Lining (Rubber); Rims (Truck, Tractor); Storage Batteries (Automobile, Truck, Tractor); Tires (Automobile, Truck, Off-the-Road); Tubes (Automobile, Truck, Off-the-Road)

Gulf Oil Corp.

P. O. Box 1166, Pittsburgh 30, Pa.

Lubricating Oils, Greases, Gasoline and Diesel Fuels

Hardinge Co., Inc.

240 Arch St., York, Pa.

Process Equipment for Grinding, Pulverizing, Drying, Thickening, Classifying, Feeding, Calcining, Cooling, Washing

Harnischfeger Corp.

4400 West National Ave., Milwaukee 46, Wis.

Complete Line of Power Cranes, Shovels, Draglines, Overhead Cranes, Hoists, Welders, Electrodes, Generators, Diesel Engines

HarriSteel Products Co.

420 Lexington Ave., New York 17, N. Y.

Woven Wire Screen Cloth

Heidenreich, E. Lee, Jr.
Consulting Engineers

75 Second St., Newburgh, N. Y.

Plant Layout, Design, Supervision; Open Pit Quarry Surveys; Appraisals—Plant and Property

Hendrick Mfg. Co.

Carbondale, Pa.

Perforated Metal Screens, Perforated Plates for Vibrating, Shaking, and Revolving Screens; Elevator Buckets; Test Screens; Wedge Slot Screens; Wedge Wire Screens; Open Steel Floor Grating

Hercules Powder Co.

Wilmington 99, Del.

Explosives and Blasting Supplies

Hetherington & Berner, Inc.

701-745 Kentucky Ave., Indianapolis 7, Ind.

Asphalt Paving Machinery, Sand and Stone Dryers

Manufacturers Division – National Crushed Stone Association
(continued)

Hewitt-Robins Incorporated

666 Glenbrook Road, Stamford, Conn.

Belt Conveyors (Belting and Machinery); Belt and Bucket Elevators; Car Shakeouts; Feeders; Industrial Hose; Screen Cloth; Sectional Conveyors; Skip Hoists; Stackers; Transmission Belting; Vibrating Conveyors, Feeders, and Screens; Design and Construction of Complete Plants; Molded Rubber Goods; Sheet Packing; Transmission Belting; Dewaterizers; Wire Conveyor Belts; Speed Reducers; Gears; Pulleys; Sheaves; Couplings

Hoyt Wire Cloth Co.

P. O. Box 1577, Lancaster, Pa.

Aggregate Wire Screens Made of Supertough, Abraso, and Stainless Steel Wire—Smooth-top, Longslot, Oblong Space, and Double Crimp Construction—For All Makes of Vibrators; Rubber Bucker Up Channel

Hughes Tool Co.

P. O. Box 2539, Houston 1, Texas

Bits—Rotary Rock

Ingersoll-Rand Co.

11 Broadway, New York 4, N. Y.

Rock Drills, Paving Breakers, Paving Breaker Accessories, Quarrymaster Drills, Drillmasters, Waterwell Drills, Down-Hole Drills, Crawl-ir Drills and Wagon Drills, Carset Bits, Jackbits, Bit Reconditioning Equipment, Portable and Stationary Air Compressors, Air Hoists, Slusher Hoists, Pneumatic Tools, Centrifugal Pumps, Diesel and Gas Engines, Blowers and Fans

International Harvester Co.
Construction Equipment Division

P. O. Box 270, Melrose Park, Ill.

Crawler Tractors and Equipment, Rubber Tired Scrapers and Bottom Dump Wagons, Off-Highway Dump Trucks, Carbureted and Diesel Power Units

Iowa Manufacturing Co.

916 16th St., N. E., Cedar Rapids, Iowa

Rock and Gravel Crushing, Screening, Conveying and Washing Plants, Asphalt Plants, Stabilizer Plants, Impact Breakers, Screens, Elevators, Conveyors, Portable and Stationary Equipment, Hammermills, Bins

Jaeger Machine Co.

550 West Spring St., Columbus 16, Ohio

Portable and Stationary Air Compressors, Self-Priming Pumps, Truck Mixers, Concrete Mixers, Road Paving Machinery, Hoists and Towers; Finishers—Concrete; Spreaders—Stone and Concrete; Truck Mixers—Concrete

Jeffrey Manufacturing Co.

815 North Fourth St., Columbus 16, Ohio

Elevator Buckets; Car Pullers; Chains; Conveyors: Belt, Drag, Apron, Vibrating; Idlers; Crushers; Pulverizers; Elevators; Feeders; Pillow Blocks; Grizzlies; Screens

Joy Manufacturing Co.

333 Henry W. Oliver Bldg., Pittsburgh 22, Pa.

Drills: Blast-Hole, Wagon, Rock, and Core; Air Compressors: Portable, Stationary, Semi-Portable; Aftercoolers; Portable Blowers; Carpullers; Hoists: Multi-Purpose, Portable; Rock Loaders; Air Motors; Trench Diggers; Belt Conveyors; "Spaders;" "String-a-Lite" (Safety Lighting Cable); Backfill Tampers; Drill Bits: Rock Core; Joy Microdyne Dust Collectors

Kennedy Van Saun Mfg. & Eng. Corp.

405 Park Ave., New York 22, N. Y.

Crushing, Screening, Washing, Conveying, Elevating, Grinding, Complete Cement Plants, Complete Lime Plants, Complete Lightweight Aggregate Plants, Synchronous Motors, Air Activated Containers for Transportation of Pulverized Material, Cement Pumps, and Power Plant Equipment

Kensington Steel
Division of Poor & Co., Inc.

505 East Kensington Ave., Chicago 28, Ill.

Oro Alloy and Manganese Steel Castings; For Shovels—Dipper Teeth, Crawler Treads, Rollers, Sprockets; For Crushers—Jaw Plates, Concaves, Concave Rings, Mantles; For Pulverizers—Hammers, Grate Bars, Liners; For Elevators and Conveyors—Chain, Sprockets, Buckets; For Tractors—Sprocket Rims, Grouser Plates; Drag Line Chain

Koehring Division
Koehring Co.

3026 West Concordia Ave., Milwaukee 16, Wis.

Excavating, Hauling, and Concrete Equipment

Manufacturers Division – National Crushed Stone Association
(continued)

LeTourneau-Westinghouse Co.

2301 North Adams St., Peoria, Ill.

Earthmoving Equipment, Motor Graders, Off-Highway Trucks, Wire Rope

Link-Belt Co.

300 West Pershing Road, Chicago 9, Ill.

Complete Stone Preparation Plants; Conveyors, Elevators, Screens, Washing Equipment, and Power Transmission Equipment

Link-Belt Speeder Corp.

1201 Sixth St., S. W., Cedar Rapids, Iowa

Complete Line of Speed-o-Matic Power Hydraulically Controlled Cranes, Shovels; Hoes, Draglines, and Clamshells, 1/2 to 3-Yd Capacities; Available on Crawler Base or Rubber Tire Mounting; Diesel Pile Hammers

Lippmann Engineering Works, Inc.

4603 West Mitchell St., Milwaukee 14, Wis.

Primary and Secondary Rock Crushers and Auxiliary Equipment such as Feeders, Screens, Conveyors, etc., Portable and Stationary Crushing and Washing Plants

Ludlow-Saylor Wire Cloth Co.

4333 West Clayton Ave., St. Louis 10, Mo.

Woven Wire Screens of Ludloy (Oil Tempered); Super-Loy (Hi-Carbon); Steel; Stainless Steel; All Other Commercial Alloys

Mack Trucks, Inc.

1355 West Front St., Plainfield, N. J.

4- and 6-Wheeled Trucks and Tractors—Gasoline- and Diesel-Powered from 5 to 12 Cu Yd Capacity with a Wide Choice of Transmissions and Front and Rear Axles with 2-, 4-, and 6-Wheel Drives; 4- and 6-Wheeled Off-Highway Vehicles from 15- to 40-Ton Capacity with Diesel Power Plants Available from 170 to 400 Hp

Manganese Steel Forge Co.

Richmond St. and Castor Ave., Philadelphia 34, Pa.

Rol-Man 11.00 to 14.00 Per Cent Rolled Manganese Steel Woven and Perforated Screens, and Fabricated Parts for Aggregate Handling Equipment

Marion Power Shovel Co.
Division of Universal Marion Corp.

617 West Center St., Marion, Ohio

Power Shovels, Draglines, Cranes, Truck Cranes—From 3/4 to 75 Yd

Marsh, E. F., Engineering Co.

4324 West Clayton Ave., St. Louis 10, Mo.

Belt Conveyors

Mayhew Supply Co., Inc.

4700 Scyene Road, Dallas 17, Texas

Blast Hole Drill Rigs

McLanahan & Stone Corp.

252 Wall St., Hollidaysburg, Pa.

Complete Pit, Mine, and Quarry Equipment—Crushers, Washers, Screens, Feeders, etc., Semi-Portable Plants

Meissner Engineers, Inc.

300 West Washington St., Chicago 6, Ill.

Engineers—Constructors—Specialists in Plant Layout, Construction-Engineering Design, Procurement, Construction Management, Quarry Surveys, Plant and Property Appraisals

Murphy Diesel Co.

5317 West Burnham St., Milwaukee 19, Wis.

Engines—Industrial Engine, and Power Units for Operation on Diesel and Dual Fuel Engines. Generator Sets, AC and DC from 64 to 165 kw. Mech-Elec Unit—Combination Mechanical and Electric Power Furnished Simultaneously

New Jersey Drilling Co., Inc.

Box 251, Route 206, Netcong, N. J.

Contract Drilling; Quarry Blast Holes

New York Rubber Corp.

100 Park Ave., New York 17, N. Y.

Conveyor Belting: Stonore, Dependable, and Cameo Grades; Transmission Belting: Silver Duck Duroflex, Soft Duck Rugged, Commercial Grade Tractor

Manufacturers Division – National Crushed Stone Association
(continued)

Nordberg Mfg. Co.

3073 South Chase Ave., Milwaukee 1, Wis.

Symons Cone Crushers, and Symons Gyratory and Impact Crushers; Gyradisc Crushers; Grinding Mills; Stone Plant and Cement Mill Machinery; Vibrating Screens and Grizzlies; Diesel Engines and Diesel Generator Units; Mine Hoists; Railway Track Maintenance Machinery

Northern Blower Co.

6409 Barberton Ave., Cleveland 2, Ohio

Dust Collecting Systems, Fans—Exhaust and Blower

Northwest Engineering Co.

135 South LaSalle St., Chicago 3, Ill.

Shovels, Cranes, Draglines, Pullshovels—Crawler and Truck Mounted

Olin Mathieson Chemical Corp.
Energy Division

East Alton, Ill.

Explosives, Blasting Caps, Blasting Accessories

Pennsylvania Crusher Division
Bath Iron Works Corp.

323 South Matlack St., West Chester, Pa.

Single Roll Crushers, Impactors, Reversible Hammermills, Ring Type Granulators, Kue-Ken Jaw Crushers, Kue-Ken Gyratories, Non-Clog and Standard One-Way Hammermills

Pettibone Mulliken Corp.

4710 West Division St., Chicago 51, Ill.

Tractor Shovels, Front End Loaders, Swing Loaders, Yard Cranes, Bucket and Fork Loaders, Motor Graders, Manganese Steel Castings, Material Handling Buckets, Clamshells, Draglines, Pull Shovel Dippers, Shovel Dippers, and Pumps

Pioneer Engineering
Division of Poor & Co., Inc.

3200 Como Ave., Minneapolis 14, Minn.

Jaw Crushers, Roll Crushers (Twin and Triple), Impact Crushers, Hammer-Mills, Vibrating and Revolving Screens, Feeders (Reciprocating, Apron, and Pioneer Oro Manganese Steel), Belt Conveyors, Idlers, Accessories and Trucks, Portable and Stationary Crushing and Screening Plants, Washing Plants, Mining Equipment, Cement and Lime Equipment, Asphalt Plants, Mixers, Dryers, and Pavers

Pit and Quarry Publications, Inc.

431 South Dearborn St., Chicago 5, Ill.

Pit and Quarry, Pit and Quarry Handbook, Pit and Quarry Directory, Modern Concrete, Concrete Industries Yearbook, Equipment Distributor's Digest

Productive Equipment Corp.

2926 West Lake St., Chicago 12, Ill.

Vibrating Screens

REICHdrill Division
Chicago Pneumatic Tool Co.

6 East 44th St., New York 17, N. Y.

Air Compressors, Rock Drills, Diesel Engines, Pneumatic Tools, Rotary and "Down-the-Hole" Drilling Machines for Exploration, Coring, Blast Holes

Rock Products

79 West Monroe St., Chicago 3, Ill.

Publications: Rock Products and Concrete Products

Rogers Iron Works Co.

11th and Pearl Sts., Joplin, Mo.

Jaw Crushers, Roll Crushers, Hammermills, Vibrating Screens, Revolving Screens and Scrubbers, Apron Feeders, Reciprocating Feeders, Roll Grizzlys, Conveyors, Elevators, Portable and Stationary Crushing and Screening Plants, Mine Hoists, Drill Jumbos, Underground Loaders, Iron Castings, Screw Washers, and Classifying Tanks

Schramm, Inc.

West Chester, Pa.

Air Compressors: Portable and Stationary, Gasoline, Diesel, and Electric Driven; Boosters; Pneumatractors, Self-Propelled; Accessories; Bits—Rock; Rotatool Bits, Carbide Insert; Drills, Drilling Equipment; Rotadrills Mounted on Pneumatractors, Trucks and Crawlers; Ready-to-Mount Rotadrills for Mounting on Used Trucks and Crawler Tractors; Rotatools for Bottom-Hole Drilling; Rock Drills; Wagon Drills; Breakers; Accessories

Manufacturers Division – National Crushed Stone Association
(continued)

Screen Equipment Co., Inc.

40 Anderson Road, Buffalo 25, N. Y.

Seco Vibrating Screens; Scales—Industrial, Aggregates, Truck

Simplicity Engineering Co.

Durand, Mich.

Simplicity Gyrating Screens, Horizontal Screens, Simpli-Flo Screens, Tray Type Screens, Heavy Duty Scalpers, D'Watering Wheels, D'Centegrators, Vibrating Feeders, Vibrating Pan Conveyors, Car Shake-Outs, Woven Wire Screen Cloth, Grizzly Feeders

Smith Engineering Works

532 East Capitol Drive, Milwaukee 12, Wis.

Gyratory, Gyrasphere, Jaw and Roll Crushers, Vibrating and Rotary Screens, Gravel Washing and Sand Settling Equipment, Elevators and Conveyors, Feeders, Bin Gates, and Portable Crushing and Screening Plants

Stedman Foundry & Machine Co., Inc.

P. O. Box 209, Aurora, Ind.

Stedman Impact-Type Selective Reduction Crushers, 2-Stage Swing Hammer Limestone Pulverizers, Multi-Cage Limestone Pulverizers, Vibrating Screens

Stephens-Adamson Mfg. Co.

Ridgeway Ave., Aurora, Ill.

Belt Conveyors, Pan Conveyors, Bucket Elevators, "Amsco" Manganese Steel Pan Feeders, Vibrating Screens, Belt Conveyor Carriers, Bin Gates, Car Pullers, "Sealmaster" Ball Bearing Units, "Saco" Speed Reducers, and Complete Engineered Stone Handling Plants

Taylor-Wharton Co.
Division Harsco Corp.

High Bridge, N. J.

Manganese and Other Special Alloy Steel and Iron Castings; Dipper Teeth, Fronts and Lips; Crawler Treads; Jaw and Cheek Plates; Mantles and Concaves; Pulverizer Hammers and Liners; Asphalt Mixer Liners and Tips; Manganese Nickel Steel Welding Rod and Plate; Elevator, Conveyor, and Dredge Buckets; Pan Feeders

Thew Shovel Co.

East 28th St. and Fulton Road, Lorain, Ohio

"Lorain" Power Shovels, Cranes, Draglines, Clamshells, Hoes on Crawlers and Rubber Tire Mountings: Diesel, Electric, and Gasoline, 3/8 to 2 1/2 Yd Capacities; "Lorain" Motor-Loader—Rubber Tire Front End Loader 1 3/4 and 2 Yd Capacity

Thor Power Tool Co.

175 North State St., Aurora, Ill.

Crawler and Hand-Held Rock Drills, Sump and Sludge Pumps, Clay Diggers, Paving Breakers, Quarry Bars, Sinker Legs, Drifters, Rock Drilling Jumbos, Raise Legs, Push Feed Rock Drills, Air and Electric Tools, Accessories, Generator Sets, Concrete Vibrators, Power Trowels, Vibratory Screeds

Timken Roller Bearing Co.
Service-Sales Division

1835 Dueber Ave., S. W., Canton 6, Ohio

"Timken"—Tapered Roller Bearings; Alloy Steel; Rock Bits

Torrington Co.
Bantam Bearings Division

3702 West Sample St., South Bend 21, Ind.

Anti-Friction Bearings; Self-Aligning Spherical, Tapered, Cylindrical, and Needle Roller; Roller Thrust; Ball Bearings

Traylor Eng. & Mfg.
Division of Fuller Co.

Allentown, Pa.

Stone Crushing, Gravel, Lime, and Cement Machinery

Trojan Powder Co.

17 North Seventh St., Allentown, Pa.

Explosives and Blasting Supplies

Tyler, W. S., Co.

3615 Superior Ave., N. E., Cleveland 14, Ohio

Woven Wire Screens; Ty-Rock, Tyler-Niagara and Ty-Rocket (Mechanically Vibrated) Screens; Hum-mer Electric Screens; Ro-Tap Testing Sieve Shakers, Tyler Standard Screen Scale Sieves, U. S. Sieve Series

Manufacturers Division – National Crushed Stone Association
(continued)

Universal Engineering Corp.
Subsidiary of Pettibone Mulliken Corp.

625 C Ave., N. W., Cedar Rapids, Iowa

Crushers—Jaw, Roll, TwinDual Roll; Hammermills, Impact Breakers, Pulverizers, Bins, Conveyors, Feeders, Screens, Scrubbers. Bulldog Non-Clog Moving Breaker Plate and Stationary Breaker Plate Hammermills, Center Feed Hammermills. Complete Line of Stationary and Portable Crushing, Screening, Washing, and Loading Equipment for Rock, Gravel, Sand, Ore; Aglime Plants; Asphalt Plants

Varel Manufacturing Co.

9230 Denton Drive, Dallas 20, Texas

Rock Bits, Drilling; Bits: Diamond, Blade, Drag

Vibration Engineering Co.

407 Hazleton National Bank Bldg., Hazleton, Pa.

Consultants on Vibration and Blast Effects; Seismograph Sales, Rental and Record Interpretation; Pre-Blast and Post-Blast Property Inspections; Seismic and Resistivity Rock Depth Surveys; Rock Velocity Measurements

Vibration Measurement Engineers, Inc.

725 Oakton St., Evanston, Ill.

Seismographic and Airblast Measurements, Seismological Engineering, Blasting Complaint Investigations, Expert Testimony in Blasting Litigation; Complete Seismograph Rental and Record Analysis Service with "Seismolog"

Webb, Jervis B., Co.

8951 Alpine Ave., Detroit 4, Mich.

Design and Construction of Complete Material Handling Systems; Conveyors—Belt and Flight; Bucket Elevators; Feeders; Forged Chain

Werco Steel Co.

2151 East 83rd St., Chicago 17, Ill.

Castings—Manganese, Alloy Steel; Screen Plates—Perforated Steel Screen Sections and Decks; Buckets; Chains; Belt Conveyors, Idlers; Dipper—Shovel; Drop Balls; Wire Cloth; Wire Rope and Related Products; Crushers, Pulverizers

Western-Knapp Engineering Co.

50 Church St., New York 7, N. Y.

Plant Design and Construction Operating Studies; Appraisals

White Motor Co.

842 East 79th St., Cleveland 1, Ohio

On- and Off-Highway Trucks and Tractors—Gasoline- and Diesel-Powered; Industrial Engines—Gasoline and Diesel; Power Units, Axles, Special Machine Assemblies; Power Generating and Distributing Systems; Batteries; All Classes of Maintenance and Repair Service

White Motor Co.
Autocar Division

Exton, Pa.

Custom Engineered, Precision Built Trucks and Tractors for On- or Off-Highway: Gasoline or Diesel Powered, 2 or 3 Axles, Single Axle to All Axle Drives; Planetary Gear Driven Vehicles for Quarry, Mine, and Construction Operations

Wickwire Spencer Steel Division
Colorado Fuel and Iron Corp.

575 Madison Ave., New York 22, N. Y.

Wire Cloth, Screens, Screen Sections, Wire Rope—Slings

Williams Patent Crusher & Pulverizer Co.

2701-2723 North Broadway, St. Louis 6, Mo.

Hammer Mills, Crushers, Pulverizers, Roller Mills, Reversible Impactors, Vibrating Screens, Air Separators, Bins, Feeders

Wiss & Associates

570 Northwest Highway, Des Plaines, Ill.

Seismological Engineers